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Center for Army Analysis

ADAPT

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13. ABSTRACT *(Maximum 200 Words)* ADAPT examines photovoltaics (PV) in both a military operations context and within a cost/benefit analysis framework. Both of these topics are now in the forefront of transforming the Army into a strategically responsive force that is dominant across the full spectrum of operations. This report illustrates that PV, as a renewable energy alternative to fossil fuels, has potential in both current and future Army deployments.			
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ANALYSIS OF DEPLOYABLE APPLICATIONS OF PHOTOVOLTAICS IN THEATER (ADAPT)

SUMMARY

THE PURPOSE OF THIS PROJECT was to develop and demonstrate a methodology for identifying and analyzing the costs and benefits of using photovoltaic systems in support of the energy needs of deployed Army forces.

THE PROJECT SPONSOR was the Office of the Deputy Chief of Staff for Logistics (DCSLOG), Transportation and Troop Support Directorate (DALO-TSE).

BACKGROUND. The early stages of this project involved a literature review of the various alternative energy technologies that are currently available and applicable for military operations. Photovoltaic technology emerged as a prime candidate largely due to its commercial availability, compatibility with current tactical energy systems, and proven system reliability. (Photovoltaics is a semiconductor technology that silently converts light energy into direct current (DC) electricity, with no moving parts, fossil-fuel consumption, or pollutant emissions.) The need for such analysis derives from a variety of influences: Executive Orders mandating efficient energy management, Department of Defense (DOD) pollution prevention directives, Headquarters, Department of Army (HQDA) focus on reliable, tactical power to support digitized operations, and the Revolution in Military Logistics (RML).

The literature review phase of this study included consideration of a Fort Monmouth report entitled *Battery Survey of Army Special Operations Forces* (July 1998). This Communications and Electronics Command (CECOM)-sponsored work focused on continuing issues resulting from the Department of the Army's mandated transition from disposable to rechargeable batteries. Issues related to forward area recharging support examining the potential of PV as a complement to existing power supply practices (e.g., generators).

METHODOLOGY. ADAPT was organized to focus on tactical, mobile military operations and total force applicability of photovoltaic energy. This project was conducted in three phases: an onsite demonstration, a cost/benefit analysis, and an assessment of potential applications of PV within the Army's operational environs.

Phase I: Onsite Demonstration (9-23 April 1999, Ft. Bragg)

The 82d Airborne Division at Fort Bragg is on the front line of the transition to rechargeable batteries. In support of the ADAPT analysis, and as a command initiative to investigate combat enhancement of the recharging mission, an in-the-field demonstration occurred that utilized a hybrid PV (PV plus generator assist) system to satisfy the energy needs of a tactical operations center (TOC). This phase served both to provide the baseline data for the ADAPT analysis and comply with the sponsor's request for an in-theater assessment. For this demonstration phase, PV power was provided by a trailer mounted 2kW (kilowatt) system with a 1,800 watt array. This PV system was used in conjunction with a military standard, gasoline powered, 5kW

(kilowatt) generator (MEP017A). The observations were considered in a follow-on assessment of the costs and benefits this alternative energy source brings to tactical, mobile military operations in the specific areas of maintenance, security, and sustainability.

Phase II: Cost/Benefit Analysis (CBA)

The CBA considered PV value-added within the context of four criteria: operational effectiveness and efficiency, cost reduction, pollution prevention, and energy savings. These criteria were individually assessed within a two-case framework. Consideration was given to both "Conventional" and "PV" power supply scenarios, with the Conventional Case representing tactical power provided entirely by a 5kW (kilowatt) tactically quiet generator (MEP802A) and the PV Case representing the utilization of PV to provide 80 percent of tactical power, with the MEP802A used to augment remaining demand. ADAPT selected the MEP802A as the Conventional Case power supply because it represented the newest mobile, tactical power provider in the 3-5 kW range. The PV Case is modeled on a 2kW PV system with a 2,048 watt array in response to feedback received during the onsite demonstration.

- In the Operational Readiness segment of the CBA, documented capabilities of the Conventional and PV scenarios were contrasted with regard to security, sustainability, and maintainability.
- In the Cost Analysis segment, cost and performance data are compared to reveal economies of scale. Variables in acquisition costs and reliability forecasts required that the two-case approach be expanded in this portion of the ADAPT project to reflect "Best Case" and "Worst Case" life cycle costing.
- In the Pollution Prevention segment of the CBA analysis, pollutants associated with the conventional and PV scenarios were categorized and scaled to identify potential reductions in emissions related to the use of PV.
- In the Energy Savings segment of the CBA analysis, fuel usage rates and associated costs are compared. The operation tempo (OPTEMPO) rates are modeled on the 82d Airborne continental United States (CONUS) garrison training rates.

Phase III: PV Potential

Insights into deployable PV potential were developed by examining a global map of those geographic areas best suited for PV power and then contrasting an overlay of historical and current global military operations. This phase also considered data from the Army's Requirements Validation Database to project the current requirements for mobile power generation equipment.

THE PRINCIPAL FINDINGS of the project suggest that:

Operational Readiness could be enhanced when PV is utilized as a power provider. This alternative energy source, in the configuration demonstrated at Ft. Bragg, is capable of providing primary power for a battalion-sized Airborne Infantry TOC. Photovoltaics could serve as a combat multiplier in its ability to enhance operational security. Survivability in critical target areas is seriously degraded by the aural signature of military standard, electric power sources. In

addition to being a silent power provider, PV configuration is flexible, with adaptations commercially available to meet a variety of in-theater demands. The 3/504th After Action Report (AAR) addressed issues related to the configuration and coloring of the demonstrated PV system. All of the recommended modifications are commercially available.

Under less than ideal conditions for PV and optimistic assumptions for the generator, there is a net present value cost avoidance of zero. The amortized breakeven point for PV is 18 years in a "Worst Case" scenario, with no purchase discounts for the PV system and, with the MEP802A maintaining 100 percent operational readiness over the 20-year life cycle (i.e., no replacement/ overhaul costs). Payback periods improve (e.g., down from 18 to 6 years) when PV systems are acquired at discounted rates similar to those associated with quantity purchases of military standard generators.

PV technology provides the Army leverage in achieving and maintaining compliance with current environmental mandates. Over the 20-year life cycle of one military standard generator, 115 tons of carbon dioxide emissions can be avoided by utilizing PV as a primary power source. Contrasted to the Conventional case scenario, PV will provide a total reduction of 237,904 lbs. (pounds) of harmful pollutant emissions.

The ADAPT Energy Savings analysis reveals a fuel savings of 71,680 lbs. over the 20-year life cycle of a MEP802A. In addition to the up-front savings in fuel cost, there will be noticeable reductions in the logistics supply and transportation pipeline that have not been quantified in the ADAPT project. The net effect is that strategic mobility could be enhanced due to less reliance on fossil fuel resupply.

Approximately 20 percent of the Army's potential mobile kilowatt generator power comes from 3-5kW systems. And of the total number of generators, 65 percent of the Army's 70,000 generators are 5kW and less. A US Army Engineer School Operational and Organizational (O&O) Plan characterizes these DOD standard generators with high noise signatures, low reliability, and costly logistical support requirements. The findings of the ADAPT Cost/Benefit Analysis indicate that PV, when fielded across the Total Army as a supplemental power provider to the MEP802A, represents a potential for savings of 817,152,000 lbs. of fuel; a reduction of 2,712,105,600 lbs. of harmful pollutant emissions; decreased maintenance burden; and an improved tactical security posture.

THE QRA EFFORT was directed by Mr. Hugh Jones, Resource Analysis Division, Center for Army Analysis (CAA).

COMMENTS AND QUESTIONS may be sent to the Director, Center for Army Analysis, ATTN: CSCA-RA, 6001 Goethals Road, Suite 102, Fort Belvoir, VA 22060-5230.

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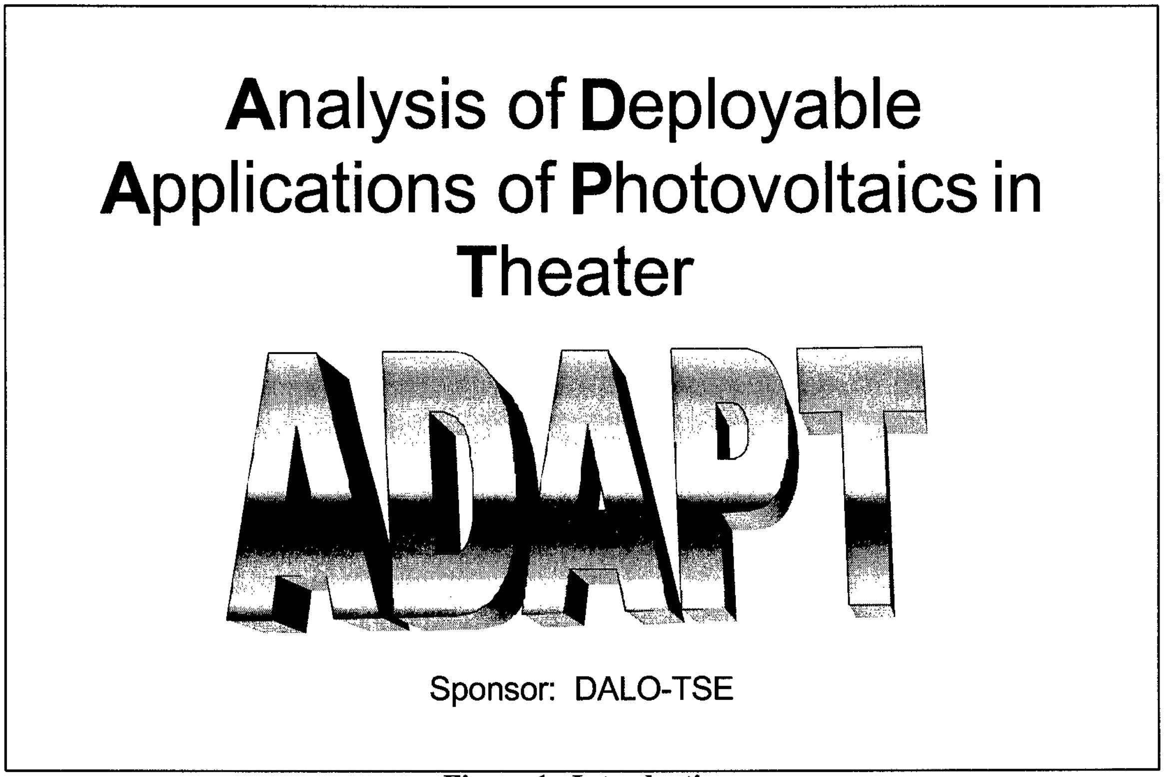

Figure 1. Introduction

This project was completed for the office of the Deputy Chief of Staff for Logistics, DALO-TSE (Army Energy Office). The work included a field demonstration of photovoltaics at Fort Bragg, NC during April of 1999.

1.1 Purpose

To develop and demonstrate a methodology for identifying and analyzing the costs and benefits of using photovoltaic systems in support of the *energy needs* of deployable Army forces.

Figure 2. Purpose

The Army is currently engaged in numerous efforts to increase strategic responsiveness while simultaneously reducing logistical support requirements. This report investigates the value added of photovoltaics as a complement to generator power, and in particular, to see whether photovoltaics as a renewable energy source can increase operational effectiveness and reduce logistic support and maintenance.

The term photovoltaics is derived from two words: photo meaning "light" and voltaics meaning "energy." Photovoltaics, which shall be called by the acronym PV in this report, is the study of light energy converted into both direct current (DC) and alternating current (AC) for use by soldiers in the field.

1.2 Future Tactical Power Challenges

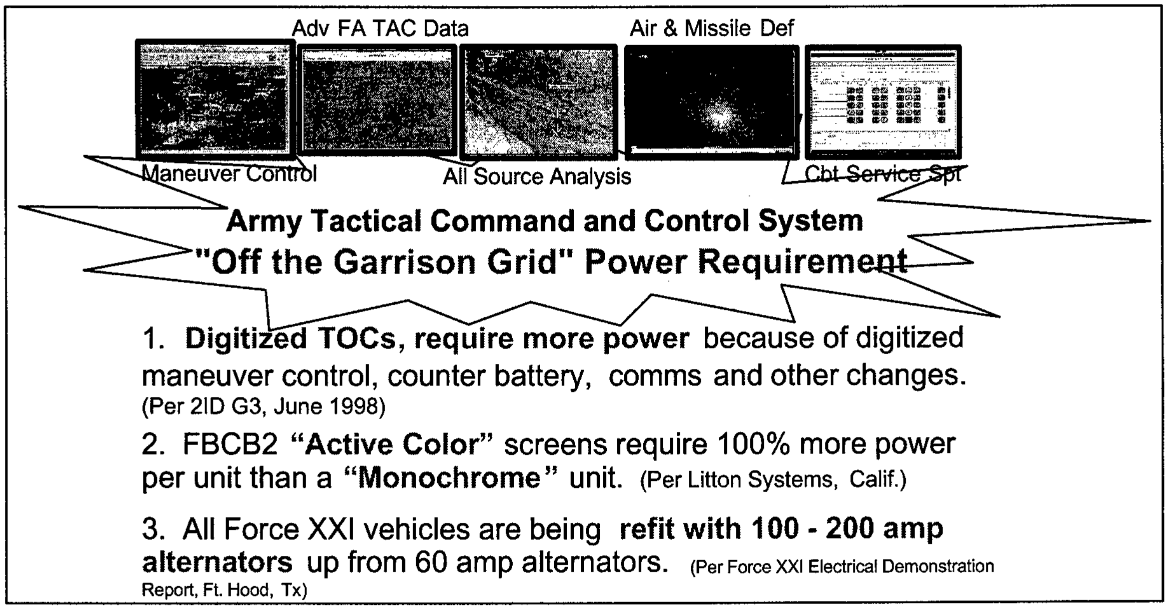

Figure 3. Future Tactical Power Challenges

The US Army is undergoing an extensive effort to modernize its forces and equipment. Part of this modernization effort is to use computer technology and digital electronics in an effort to enhance military operational capability and readiness. To that end, it has been observed that in order to "digitize" its maneuver forces and equipment, more electric power is required in the field. Currently, this power comes from three primary sources: (1) vehicle engines and batteries, (2) auxiliary power units (APUs), and (3) dedicated generators.

All these forms of off-the-grid power are tested, reliable, and available. Currently, all military standard APUs and dedicated generators are being upgraded to the newer family of tactically quiet generators (TQG). These units are generally quieter, burn less fuel, and are more reliable than their predecessors, but are also more expensive. Moreover, recognizing that current generator maintenance challenges exist, the Army is investigating a new family of generators within the 5kW (kilowatt) to 60kW power range called the Advanced Medium-Sized Mobile Power Systems (AMMPS). This new system of generators is being planned for Force XXI and the Army After Next.

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CHAPTER 2 BACKGROUND

2.1 Executive Orders, DOD Directives, and Army Policy

These are the primary laws and executive orders governing energy policy in the Army. The purpose of much of this legislation is to protect the environment; the air we breath, the water we drink, and the land we live on. Because fossil fuels are a "nonrenewable" energy source, it makes sense to conserve this resource as much as possible.

In June of 1999, President Clinton signed into law Executive Order number 13123, Greening the Government Through Efficient Energy Management. This order provided a requirement that cost-benefit analysis be performed for all energy sources used by the Federal Government.

PUBLIC LAWS:

Pollution Prevention Act of 1990...established a hierarchy for pollution management as national policy--declaring that pollution should be prevented or reduced at the source

Energy Policy Act (PL 102-486 - EPACT) ... enacted to increase the use of renewable energy and energy efficiency in the industrial, commercial, Residential, and federal sectors of the economy

EXECUTIVE ORDERS:

12759 Reduction in Energy Use (4/91) ...Establishes energy efficiency goals for federal buildings/facilities and industrial processes.

12856 Pollution Prevention Requirements (8/93) ...establishes goals in the federal sector for pollution prevention

13123 Greening the Government Through Efficient Energy Mgmt (6/99) ... through *cost-effective investment in energy efficiency and in renewable energy*. Each federal agency will reduce its greenhouse gas emissions.

Figure 4. Executive Orders, DOD Directives, and Army Policy

2.2 Army Chief of Staff Guidance

- *Aggressively reduce logistics footprint* by prioritizing solutions which optimize smaller, lighter, more reliable, fuel efficient, and more survivable options

(CSA remarks at AUSA, October 1999)

- This commitment to change will require a comprehensive transformation of the Army. We will jump start this process by *investing in today's "off-the-shelf" equipment . . . and begin a search for the new technologies that will deliver the material needed for the objective force.*

(CSA remarks at AUSA, October 1999)

- *Reliable tactical electrical power is needed to support operations* on a digitized battlefield and insure information dominance.

(Army Plan FY 2002-2017)

Figure 5. Army Chief of Staff Guidance

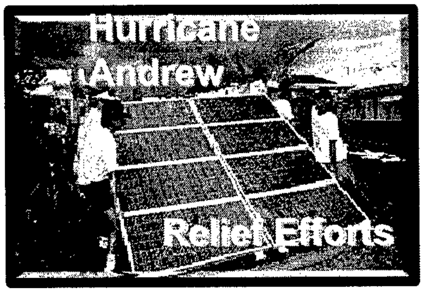
Chief of Staff General Eric K. Shinseki, in his address to the Eisenhower Luncheon on October 12, 1999 at the 45th annual meeting of the Association of the United States Army, stated his vision for the US Army for the new millennium:

> "Soldiers on point for the Nation transforming this the most respected Army in the world, into a strategically responsive force that is dominant across the full spectrum of operations."

This project provides insight into the question "Can PV contribute to this vision for the Army of the 21st century?" This study investigates deployable PV as a new power technology for the Army that holds certain potential for reducing logistical requirements and providing new capabilities for increased sustainability. Sustainability, agility, versatility, and reduced logistical requirements are all tenets of GEN Shinseki's vision for today's Army and one in which PV may add value in all these categories to forces in the sustaining base (i.e., posts, camps, and installations) and for deployed forces.

2.3 Military PV Usage

Photovoltaics (PV)



PV Powered Systems help today's military in the following ways:

For small-scale contingencies (SSCs), the **Army** has used FEMA's PV systems at several natural disaster locations (the most recent having been Hurricane Bonnie in September of 1998 at the Outer Banks, North Carolina).

The **Air Force** is using PV to aid downed fliers in being able to recharge their emergency radio batteries.

Alternative Power Sources Program

Marines have created a power office at Quantico that is specifically looking at ongoing PV applications and other *nonfossil fuel* power alternatives.

Figure 6. Military PV Usage

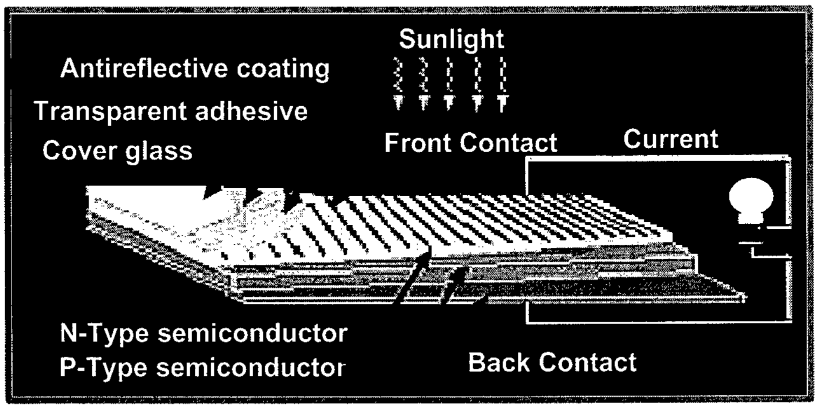
The Army has employed various PV systems in small-scale contingencies over the past decade. Other services have used various PV-powered modules for similar missions.

Historically, PV has not been able to compete with local electric power (i.e., on-the-grid) utilities because of cheap electric power. However, off the grid, away from inexpensive power, PV is more attractive. That is why PV can often be found in less developed countries with limited natural hydroelectric potential or inadequate power grids. Today's major PV applications can be found in the middle of deserts and mountainous regions where it is too costly for power companies to run power lines.

The US Army uses diesel- and gasoline-powered generators for its off-the-grid power requirements. This report explores the potential for using a hybrid of fossil fuel generators and PV power as an alternative for off-the-grid power generation.

2.4 How PV Works

Photovoltaics (PV)



Hybrid PV Systems use batteries to store energy until it's needed.

PV Power: As a "rule of thumb," for a single poly-crystal type module, one can expect between 100-200 watts per square meter.

- 1980's PV technology was limited to capturing less than 10% of the sun's available wattage per square meter
- Today, we are approaching 15% efficiency with new forms of silicon semi-conductors.

Figure 7. How PV Works

PV energy is generated by chemical energy, which is based on poly-crystal semiconductor technology combined with lead-acid batteries. Because PV energy comes from the sun, it is necessary for nighttime power requirements to be met via a battery bank of stored PV energy--to be recharged the next day. PV energy is not as efficient as fossil fuel generators on a British thermal unit (BTU) basis of comparison. For example, PV technology today can at best convert a maximum 15 percent of an available 1,000 watts/hour of sun energy per square meter. Converting this wattage to BTUs provides 2,500 BTUs available to use from the PV method.

In comparison, when a gallon of diesel fuel is converted to BTUs, the translation yields about 130,000 available BTUs for power production. Given that gasoline generators are at best 30 percent efficient and diesel generators 50 percent efficient, more power per available BTU can be obtained from fossil fuel generators than from PV.

Fossil fuel generators convert both mechanical and chemical energies into power. The chemical combustion of fossil fuels, combined with the mechanical energy (i.e., moving parts) that produces friction are the primary reasons why generators create so much heat as a by-product. Likewise, generators require periodic maintenance and part replacement because of wear and tear. Unlike generator power, PV energy is produced with no moving parts or combustibles and requires much less maintenance than generators.

2.5 PV Building Blocks

The first practical solar cells were made less than 30 years ago, and the theoretical groundwork for understanding the photovoltaic phenomenon was laid only at the beginning of this century.

As early as the end of the 19th century, the phenomenon of light shining on a liquid cell producing an electric current was noticed, but no explanation was available. Then just after the start of the 20th century, Albert Einstein offered an explanation for a similar phenomenon, the "photoelectric effect" that brought him the Nobel Prize in physics (1921). This laid the groundwork for an understanding of what is now called the "photovoltaic effect."

To observe the photovoltaic effect, light was shined on a metal surface and an electric current could be detected coming off the metal. Einstein explained the observed phenomenon by capitalizing on the recently introduced idea of "quantized" energy levels and described light itself as being made of a flow of minuscule "photons" or particles of light energy. When photons impinge on metal, some "knock out" electrons from metal atoms, much like a billiard ball will knock another ball away when the two collide. Further application of the quantum concept led to the development during the 1930s of a whole new way of dealing with matter and energy called Quantum Mechanics. This science was used to develop the new solid state technology which embodies the photovoltaic arrays pictured below.

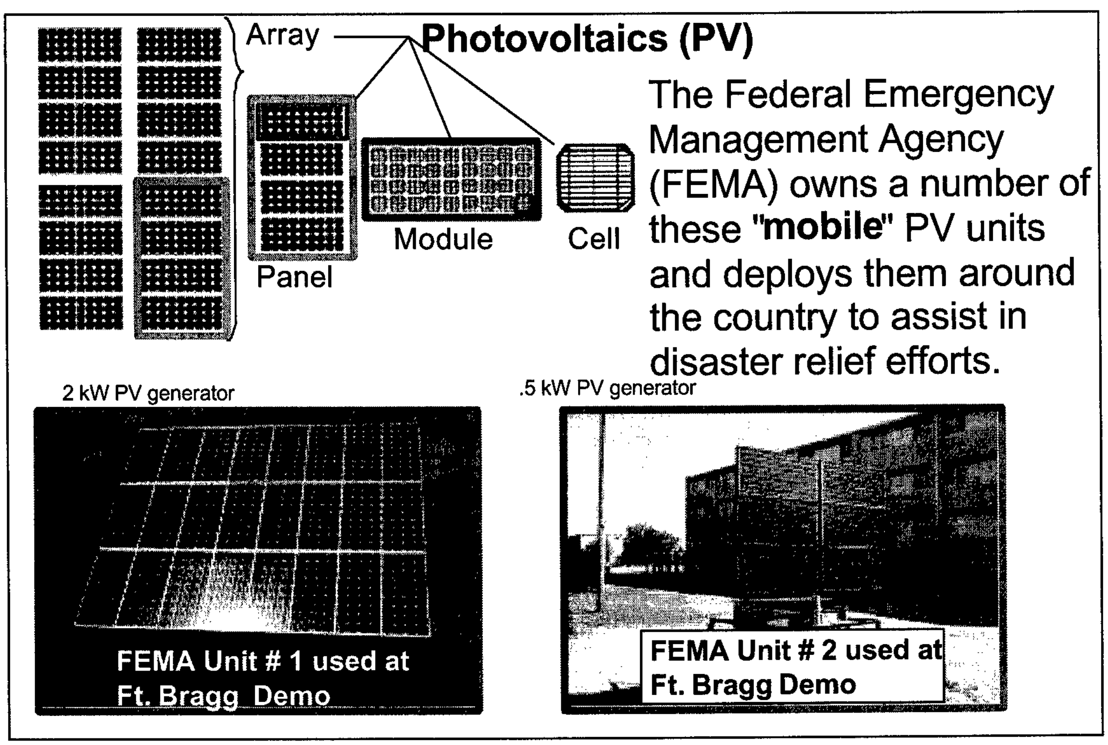


Figure 8. PV Building Blocks

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CHAPTER 3 METHODOLOGY

3.1 Overvview

Evaluating photovoltaics potential in theater required a three-phase approach:

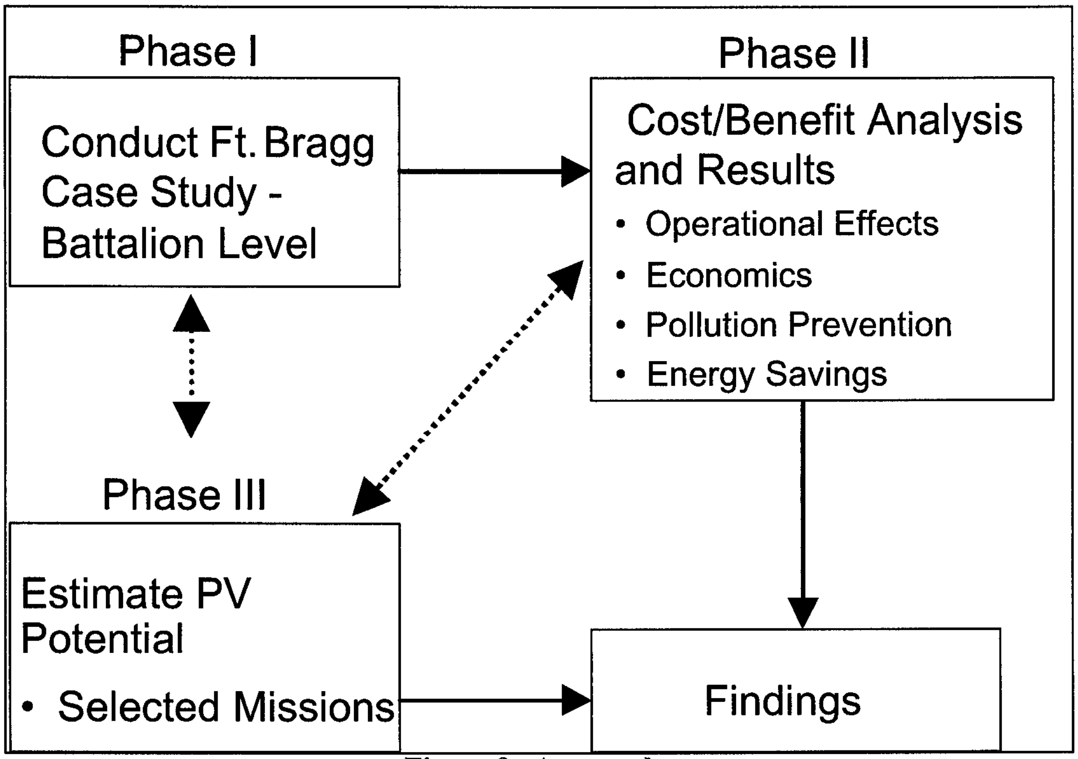

Figure 9. Approach

Evaluating the potential of photovoltaics in theater incorporated a three-phase approach that led to several findings - especially regarding strategic responsiveness.

Phase I. Employed an onsite analysis to gather first-hand data and to provide light infantry forces "in-the-field" a demonstration of the capabilities and limitations of current photovoltaic technology.

Phase II. Applied four cost/benefit analyst criteria to evaluate PV value added, which is reflected in terms of military operations, economics, pollution prevention and energy savings. This was an iterative process that at times drew from a working knowledge of in-the-field power requirements and electrical engineering concepts.

Phase III. PV Potential is key to understanding the missions that PV may be able to undertake. In our limited demonstration, as a basis, we compared a single 2kW photovoltaic generator as assisted by a single 5kW fossil fuel gene4rator with a single 5kW fossil fuel generator operating alone. Both systems were alternatively used to power a battalion tactical operations center.

However, there may be missions for which PV is unsuited and there are geographical locations where PV is unproductive. (i.e., Antarctic and Arctic locations that have extended periods without sunlight)

Each of these phases will be discussed in further detail in the remainder of this report.

3.2 Synopsis of Events: The Road to Ft. Bragg

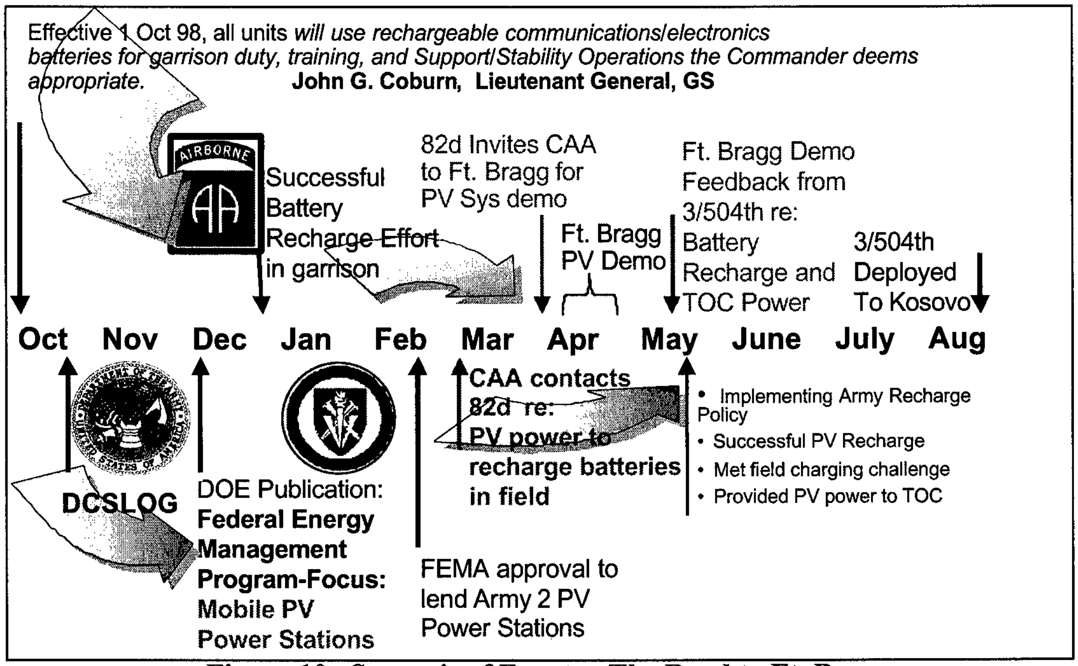

Figure 10. Synopsis of Events: The Road to Ft. Bragg

ADAPT began a literature review of alternative energy technologies available today for applications in the field. Part of the impetus to do this came from a CECOM, Ft. Monmouth report entitled Battery Survey of Army Special Operations Forces (July 1998) by Mr. Michael R. Miller and Mr. Fee Chang Leung. This work addressed Special Operations Forces' (SOFs') usage of batteries and requirements for technology upgrades. The major topic of interest here was the mandated transition from primary batteries to rechargeables as illustrated by the former DCSLOG, LTG Coburn's, order (seen in Figure 10). The main findings from this report were that although battery recharging is now policy, the following issues required further analysis:

- **Increased Weight.** Rechargeable batteries weigh more than disposable batteries.
- **Up-front Costs.** Rechargeable batteries are made from more expensive materials than disposable batteries and require charging equipment.
- **Forward Area Recharging.** Where and how to recharge batteries for forward deployed light infantry is critical.

This last finding served as a catalyst that propelled this analysis into a search for deployable, quiet power for front-line soldier battery recharging missions.

This work eventually led CAA to the 82d Airborne Division at Ft. Bragg, North Carolina because the 82d is at the forefront of the battery transition process. The timeline pictured above is in two parts--the upper being the 82d Airborne's milestones. The part below the months are those events undertaken by CAA. Together, they provide the reader a road map as to how PV and generators were combined to investigate off-the-grid alternative power solutions available to soldiers in the field.

The Fort Bragg demonstration was supported by the Federal Emergency Management Agency (FEMA) and the Department of Energy. The demonstration was given in a field exercise to the 504th Parachute Infantry Regiment of the 3d Battalion, 1st Brigade, 82d Airborne.

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CHAPTER 4 ANALYSIS: PHASE I

4.1 3/504th Battalion Training Exercise

Primarily because of the 3/504's success in implementing the Army's rechargeable battery policy--and its associated cost savings--they were interested to see if PV could help in the battery recharging mission in the field, away from normal garrison electric power. They had also experienced mechanical problems with military standard, fossil fuel generators and were interested in looking at alternatives that reduced their dependency and maintenance workload on military standard generators.

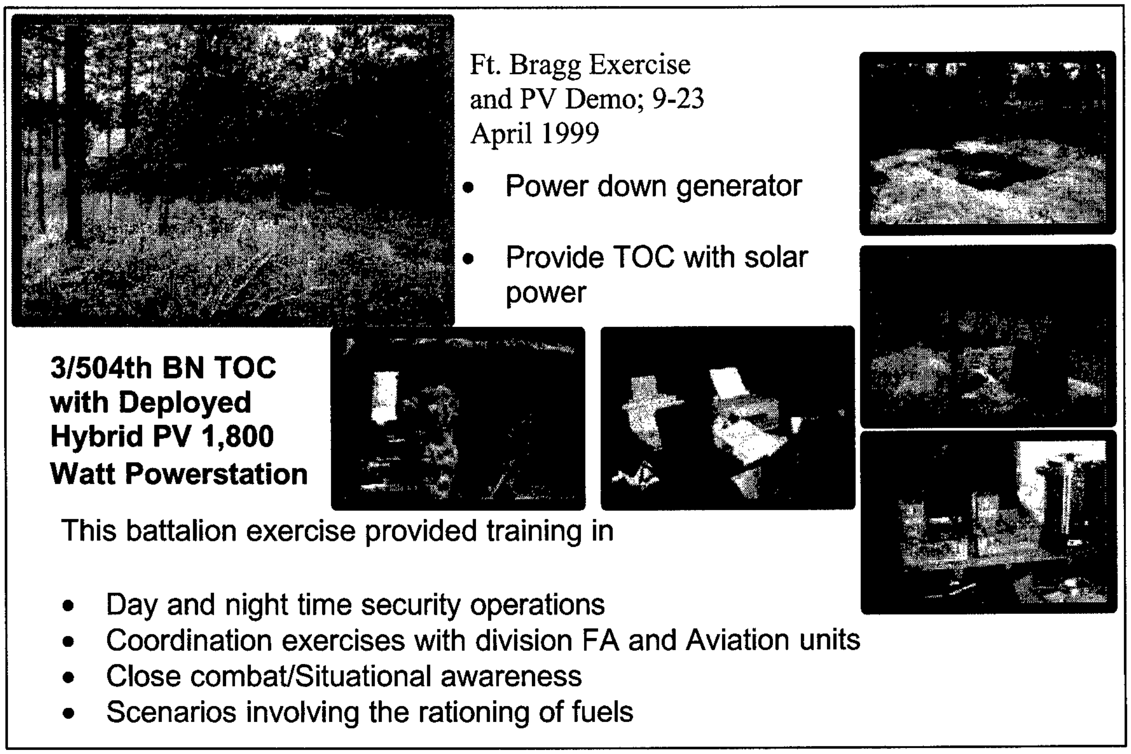

Figure 11. 3/504th Battalion Training Exercise

During the 9 days in the field using the hybrid PV and 5kW generator, the battalion was receptive to the demonstrated PV potential. Their follow-on after action report (AAR)--included in this report--indicated mission critical value added and support for this new technology in the following ways:

First, because PV is silent, daytime and nighttime security operations made the battalion TOC less vulnerable. (On the nights when the generator was running, it could be heard for a considerable distance beyond the defensive perimeter of the battalion TOC and therefore was an easier target to find.)

Second, PV reduced logistical support to the 3/504. The 5kW generator that was used in the Fort Bragg case study was an essential part of both the Conventional and PV Cases. It complemented the quiet power of the PV. For example, when tactical quiet was required at night, the PV was used. Recharging with the generator was done only during daylight, and then only in conditions as directed by the staff.

Springtime weather conditions during the field exercise provided 3 days of sunny weather, 3 days of continuous hard rain, and 3 days of cloudy weather. The periods of inclement weather decreased the PV recharging rate to less than that available on sunny days. The fact that all days are not sunny is the primary reason to rely on the generator. The question of whether or not the 5kW generator could be reduced to a 3kW generator (or the 3kW reduced to a 2kW) is a question beyond the scope of this report.

On average, it took the PV battery unit about 6 hours to fully recharge after reaching a low battery level of 20 percent state of charge. This meant that the generator was running 6 hours for every 30 hours of power requirement. (This reduced generator "on" time and, accordingly, fuel requirements by 80 percent). One could assume that this might also reduce generator maintenance by approximately 80 percent.

4.2 Principal Findings

The key finding from this field demonstration was that with some modifications of the deployable unit, PV could be used to provide the primary power for a battalion sized, Airborne Infantry tactical operations center.

For their part the 3/504th provided a written after action report detailing those modifications that would enhance the operational readiness of mobile Army PV. This list and its status to date are discussed on the next page.

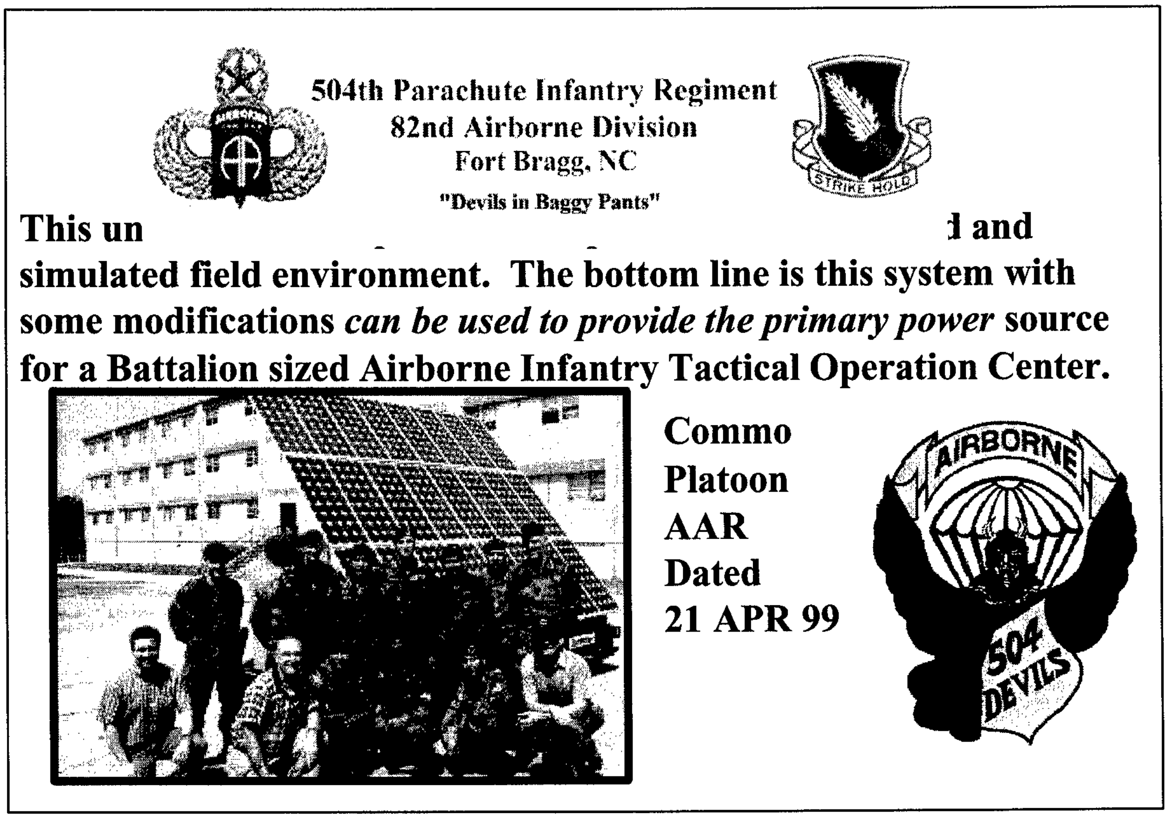

Figure 12. Principal Finding

4.3 Ft. Bragg Operational Feedback

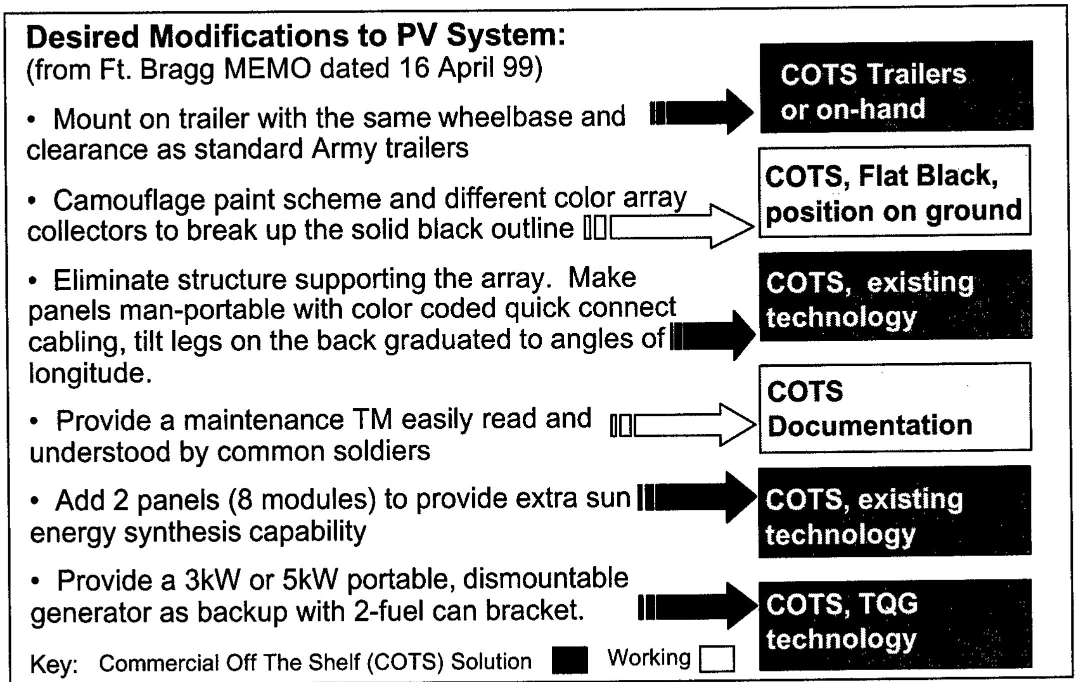

Figure 13. Ft. Bragg Operational Feedback

Figure 13 is a complete list of the Fort Bragg enhancements that they recommended be included in future variants of the trailer-mounted, hybrid PV power unit. The suggestions in green are those which after review, could readily be accomplished. Those remaining suggestions which would take longer to make acceptable or to modify to meet a stated concern are pictured in yellow. Inasmuch as those concerns in green have already been met or are currently in commercially provided off-the-shelf solutions, we will not address them further here. The two suggestions in yellow do warrant the following explanations.

- The PV unit, when configured in its power-producing mode, had a large silhouette with sharp, well-defined outlines. The concern here was that such a large structure might be visible to an enemy from the ground or from the air and as a result, increase the TOC's vulnerability. There are two solutions to this which are currently being explored. The first solution is to provide a camouflage paint scheme over the entire PV array. The paint scheme, of course, would be intrinsic to the solar collectors. The National Energy Renewable Energy Laboratory and the Army's Communications and Electronics Command are both working this requirement.

- An alternative solution to the camouflage issue is to eliminate the array and array structure as pictured earlier and replace it with flat black modules on the ground. This reduces both the system's height and eliminates the sharp outlines of the demonstrated PV system.

- Documentation for the soldier will need to be substantially reviewed and rewritten--possibly with the help of soldiers that will have had the opportunity to use mobile PV in the field.

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CHAPTER 5 ANALYSIS: PHASE II

5.1 Cost/Benefit Analysis

Does investment in mobile PV for Army deployable forces provide value added?

Investment Criteria:

- Operations
- Pollution Prevention
- Economics
- Energy Savings

2 Cases Analyzed:

- CONVENTIONAL Scenario
  - Generator provides power in the field (100% of mission amp hour requirement supplied by generator)
- PV Scenario
  - PV provides primary power in the field (80% of mission amp hour requirement supplied by PV, 20% by generator)
  - Generator assist (used in addition to sun for PV battery recharge)

Figure 14. Cost/Benefit Analysis

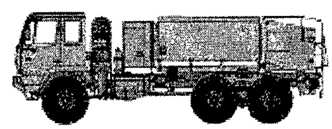
The cost/benefit analysis, determines if PV adds value to the concept of mobile electric power. For ADAPT, "adding value" means providing enhanced operational effectiveness and efficiency, preventing pollution, reducing costs, and saving energy. The principal indicator for measuring enhanced military operations was the 3/504th's AAR from the field demonstration. The measure of effectiveness for economics was dollars saved; for energy savings, gallons of fuel not burned; and for pollution prevention, tons of pollution prevented.

A two-scenario approach is employed to highlight the different capabilities of PV and generators that add value to the 82d's mission. The conventional scenario used 100 percent generator power to meet the battalion TOC power requirement while in the field. Whereas, the hybrid PV scenario (PV plus generator assist) utilized the sun's energy to provide 80 percent of the battalion TOC's in-the-field power requirement with only 20 percent supplied by generator power.

5.2 General Assumptions and Parameters

The general assumptions and parameters that follow were important to the overall approach and conduct of this project. This analysis included assumptions to complement the actual field data gathered throughout the April 1999 demonstration. This method helped to provide realistic best case and worst case scenarios for both PV and generators.

- 5kW generator for primary power & PV assist
- Similar trailer requirements
- Fuel is always available



- 20-year life cycle for PV and generator
- OPTEMPO is 1600 hours per year
- Ambient conditions at Ft.Bragg
- Costs are in FY 99$

Figure 15. General Assumptions and Parameters

This analysis assumes that 20-year life cycle costing for both the PV and the generator(s) are the norm. OPTEMPO was obtained from onsite first hand experience with the 82d Airborne Division.

The basis for comparison is a single 2kW PV generator as assisted by a single 5kW fossil fuel generator compared to a single 5kW fossil fuel generator operating alone.

The PV demonstration at Fort Bragg, NC had springtime weather conditions that provided expected levels of solar insolation for April at Fort Bragg. However, there are places in the world that have much better and much worse solar insolation values. For example, during the Arctic winter when the sun does not shine for months, this would be the worst PV location possible. In comparison, desert climates provide even better solar insolation parameters than at Fort Bragg.

The following summary statements come from firsthand observation of the power units in the field during the period 9 - 23 April 1999 at Ft. Bragg. Life cycle data were obtained from the Project Manager Mobile Electric Power (PM-MEP) and from the Department of Energy.

5.3 Observations: Operational Readiness

Security	Ops Friendly	Durability	Reliability
Conventional Case: 100% Generator			
• Lower visibility • Greater heat signature • More noise	• Much greater SOP maintenance • More labor intensive	• Ruggedized • 10 & 20 year life cycles depending on kW rating	• Good theoretical reliability of 3kW generators • Less than planned
Photovoltaic Case: 80% PV and 20% Generator			
• Greater trailer height visibility • Less heat signature 80% of the time • Noiseless 80% of the time	• Much lower maintenance • Less overall labor	• Modules ruggedized • Durable lead acid batteries • 20 year (+) life cycles	• PV system has no "moving" parts • Reliable electronics • More sun is better

Figure 16. Observations: Operational Readiness

Figure 16 summarizes observations made regarding operational readiness for both cases in the Fort Bragg demonstration. The Conventional Case was comprised of the single fossil fuel generator providing 100 percent of the power requirement for the 3/504th battalion TOC. The Hybrid PV Case used the PV unit and the generator to provide power to the TOC. The power breakdown in the PV case was approximately 80 percent supplied by the PV system and 20 percent coming from the generator.

5.4 Economic Analysis: Cost Inputs

These are the primary discounted cost inputs that were used to generate the economic analysis. Note that for each case, there are corresponding initial investment and operations and maintenance (O&M) costs. Additionally, we show battery and electronic replacement costs and battery life cycle effectiveness measured in years. Lastly, these costs are used to calculate 20-year O&M and 20-year battery replacement costs.

Scenarios:	CONVENTIONAL		PV	
	Economy of Scale for Generator not PV	Economy of Scale for Generator with Gen replacement	Economy of Scale for Generator not PV	Economy of Scale for Gen & PV with Gen replacement
Generator	(Figure 1)	(Figure 2)	(Figure 1)	(Figure 2)
Investment	6,906	27,624	6,906	6,906
Annual O&M	3,109	3,109	610	610
20 year O & M	$62,180	$62,180	$12,200	$12,200
PV				
Investment (Includes batteries)	—	—	33,232	22,155
Annual O&M	—	—	91	91
20 year O & M	—	—	$1,820	$1,820
PV Battery				
Replacement	—	—	2,882	2,882
Annual O&M	—	—	9	9
Life (Yrs)	—	—	5	5
20 year Replace & O & M	—	—	$8,826	$8,826

Figure 17. Economic Analysis: Cost Inputs

PV Worst Case Scenario (Chart 1, Figure 18):

The worst case for PV is driven by two factors:

- no economy of scale for the purchase of PV units, and
- single generators that can last 20 years.

PV Best Case Scenario (Chart 2, Figure 18):

The best case for PV is driven by the inverse of the above:

- economy of scale for the purchase of 100 PV units, and
- single generators that do not last 20 years (i.e., without replacement/overhaul).

5.5 Economic Analysis: Worst/Best Cases

From the previous page, we determined initial costs and discounted outyear O&M costs to produce Figure 18.

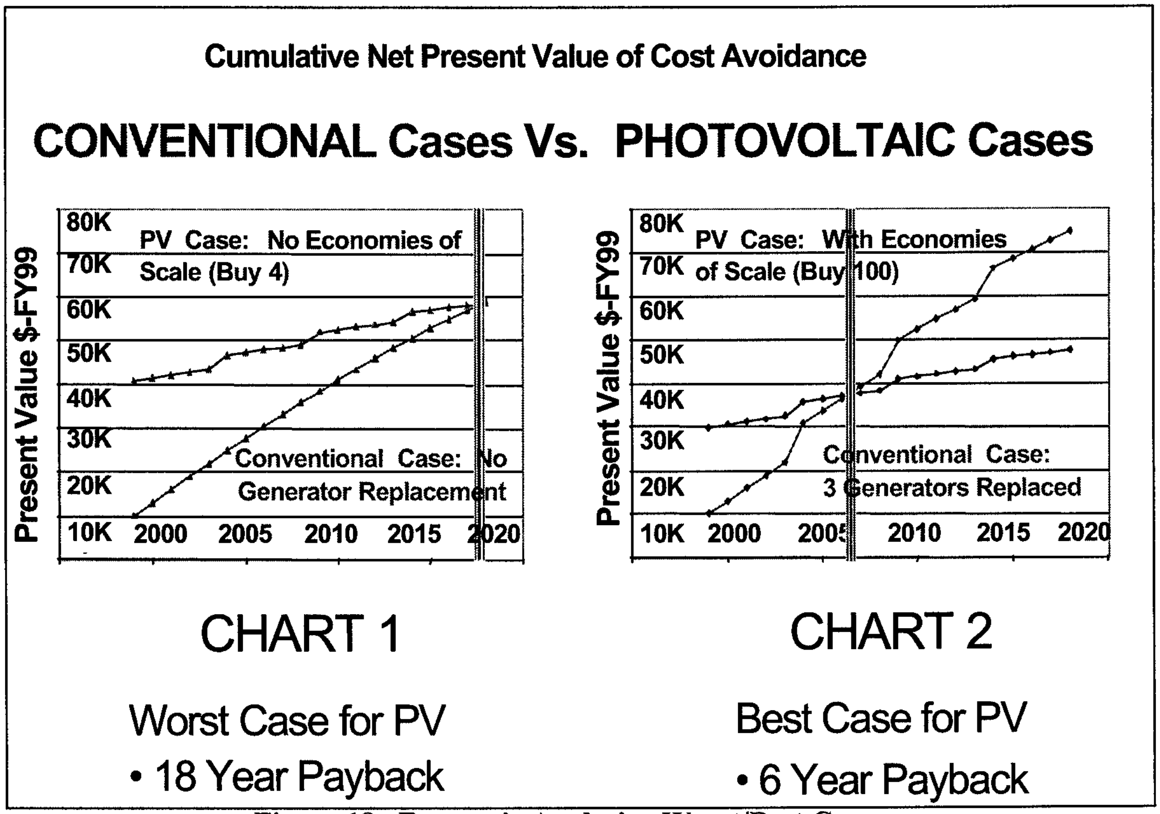


Figure 18. Economic Analysis: Worst/Best Cases

Chart 1: Worst Case PV Scenario

The PV Case has initial higher cost beginning with 1999 for two major reasons.

1. The US Army buys generators at a discount because they buy them in volume (measured in thousands). The initial TQG 5kW generator cost is a discounted cost, on a General Services Administration (GSA) schedule, because of this volume discount. Conversely, the PV case represents a discount given that only four systems are purchased.

2. The PV case also includes the cost of the same generator as in the Conventional case. The jagged line for the PV cases in Charts 1 and 2 comes from the fact that every 5 years, new batteries and electronics are purchased for the PV system. Although not an assumption listed previously, battery life of only 5 years is a conservative estimate. More likely, these deep cycle, ventilated, Courtland batteries should last at least twice that estimate.

One can see from Chart 1, Figure 18, that under less than ideal conditions for PV and optimistic assumptions for the generator, net present value cost avoidance of zero. That is, this analysis shows the competing economics--over 20 years--of the PV case versus the generator case are equal. The difference lies in how long it takes the PV to pay for itself. Chart 1 illustrates that it takes the PV about 18 years to pay back the initial investment.

Chart 2: Best Case PV Scenario

1. The purchase of 100 PV units provides a decreased cost per PV unit by up to one-third of the original cost. So instead of a PV cost in the worst case scenario of $33,232, the best case scenario uses a volume discount of 33 percent, or $22,155.

2. In the best case PV scenario, we assume that five generators would be used throughout the 20-year costing life cycle (and not a single generator as for the worst case PV scenario).

Lastly, from Chart 2, Figure 18, we see that it takes about 6 years for the PV to pay for itself. Other factors such as greater usage of diesel fuel would also be more favorable to PV and would lower the payback period even more.

5.6 Pollution Prevention

One of the main benefits of the hybrid PV scenario is pollution prevention. Fossil fuel burning generators produce many harmful pollutants which, in total, have negative impacts on the atmosphere and the earth. Figure 19 compares a 2kW PV generator assisted from a 5kW fossil fuel generator with a single 5kW fossil fuel generator operating alone.

Pollutant	20 Year Savings (lbs of pollutants)
NOx	6,157
CO_2	228,982
CO	1,326
SOx	405
PM	433
Aldehydes	98
Exhaust	489
Crankcase	14
Total :	**237,904 lbs**

Figures are the differences between Conventional and PV cases

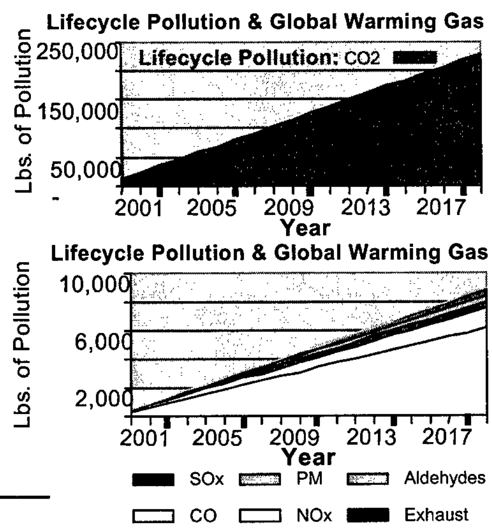


Figure 19. Pollution Prevention

Figure 19 shows the breakdown of pollution from fossil fuel generators into their various pollutant categories. There is no pollution from PV to report.

Possibly the most harmful of all generator pollutants is carbon dioxide. Although this gas is produced in nature, too much of this gas is--according to the EPA--harmful to the earth's atmosphere. Carbon dioxide alone accounts for over 115 tons of harmful global warming gas over 20 years when comparing the difference between the hybrid PV scenario and the conventional scenario.

5.7 Energy Savings

Energy savings is important to the Army not just in terms of dollars saved but because of the sustained logistical impact as well. Given that fossil fuels such as JP8 must be stored, transported, and delivered to its destination, this whole "logistical support system" is reduced by the positive impact of PV on energy savings. In other words, for every truckload of fuel saved, this also means that it is one less truckload of fuel delivered. In the long term, there are aspects of the logistical "tail" that would need to be reassessed because of this benefit.

CONVENTIONAL Case:

5kW Military Standard, DED generator used for 1,600 hours per year at Fort Bragg over 20 years will require 89,600 lbs. of fuel.

PV Case:

20 year fuel use for a 2kW PV System with a 2,048 Watt Array used for 1,600 hours per year at Fort Bragg with 5kW DED generator assist requires 17,920 lbs of fuel.

Fuel Savings is 89,600 lbs

17,920 lbs.

71,680 lbs. of fuel saved

(about 11,400 gallons)

Figure 20. Energy Savings

Of course, every mission may not be 80 percent PV and 20 percent conventional--but consider this; if the case were only 50 percent PV and 50 percent conventional, would saving 50 percent of the normal fuel use be worth it? Would it be worth saving 50 percent of the fossil fuels that

are currently being transported? And last, could further savings be made in the equipment that stores fuel and that transports fuel if we were using only half of what we use now for selected missions? These questions are posed because it is hoped that the purpose of ADAPT--that of examining PV potential in theater--can be further developed into "feasible uses of PV" by those commands requesting and procuring PV prototypes. Each PV prototype would be tailored to meet the mission requirements of the requesting Agency or Division--in a manner similar to the 82d Airborne's After Action Report.

5.8 Cost/Benefit Analysis Findings

To review, the 82d Airborne Division's 3/504th (1st BDE) gave mobile PV high marks for its ability to enhance its mission. As a follow-on comment to this story, the 3d Battalion, 504th Parachute Infantry Regiment, left for Kosovo in September of 1999. Throughout the fall of 1999, CAA received numerous e-mails from Task Force 3/504 at Camp Bondsteel in Kosovo, requesting to be put at the "front of the queue" for any prototype Army PV units. It seems that local power is nonexistent or undependable and that the constant noise of big generators is having a negative impact on operational readiness (constantly having to transport gasoline) and on being able to sleep with all the generator noise. Additionally, the battalion command thought that PV would also impact on its combat service support structure (for less generator maintenance) while simultaneously improving its sustainability and maneuverability.

Operational Readiness

Soldier in the field found PV improved his efficiency

PV case enhances operational readiness

Economics

PV case is lifecycle cost effective

Pollution Prevention

200,000 pounds of pollution eliminated in PV case (predominantly global warming gases)

Energy Savings

11,000 gallons of fuel saved in PV case

Figure 21. Cost/Benefit Analysis Findings

Economic analysis shows life cycle cost effectiveness for both the PV and Conventional cases. In comparing theoretical PV payback between the conservative and optimistic cases, reality suggests that payback will occur somewhere in between the cases shown.

Pollution prevention is clearly in favor of the hybrid PV case as is energy savings.

In addition to the aforementioned Cost/Benefit Analysis Findings, it is important to note that as far as costs are concerned, there are other cost savings, not monetized in this report, with significant impact that should be high lighted. These additional categories are:

Training Readiness. Training readiness assumes certain costs which, in the case of the Ft. Bragg demonstration, "took personnel away from training to tend to the needs of the generator(s)." Examples include holes that must be dug for both the generator and the gasoline storage. On one occasion, Army personnel had to return generators from far in the field to battalion maintenance and then return again (110-mile round trip).

Other Logistical. For units in the field, there is a large logistical tail that is expensive to maintain and to man. These are the costs associated with fuel trucks, fuel depots, travel to and from front-line units or petroleum, oils, and lubricants (POL) centers, and fuel-testing.

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CHAPTER 6 ANALYSIS: PHASE III

6.1 PV Potential vs Feasibility

To this point, we have covered the background and cost/benefit analysis for the Fort Bragg cases. This chapter focuses on an assessment of PV potential for selected applications.

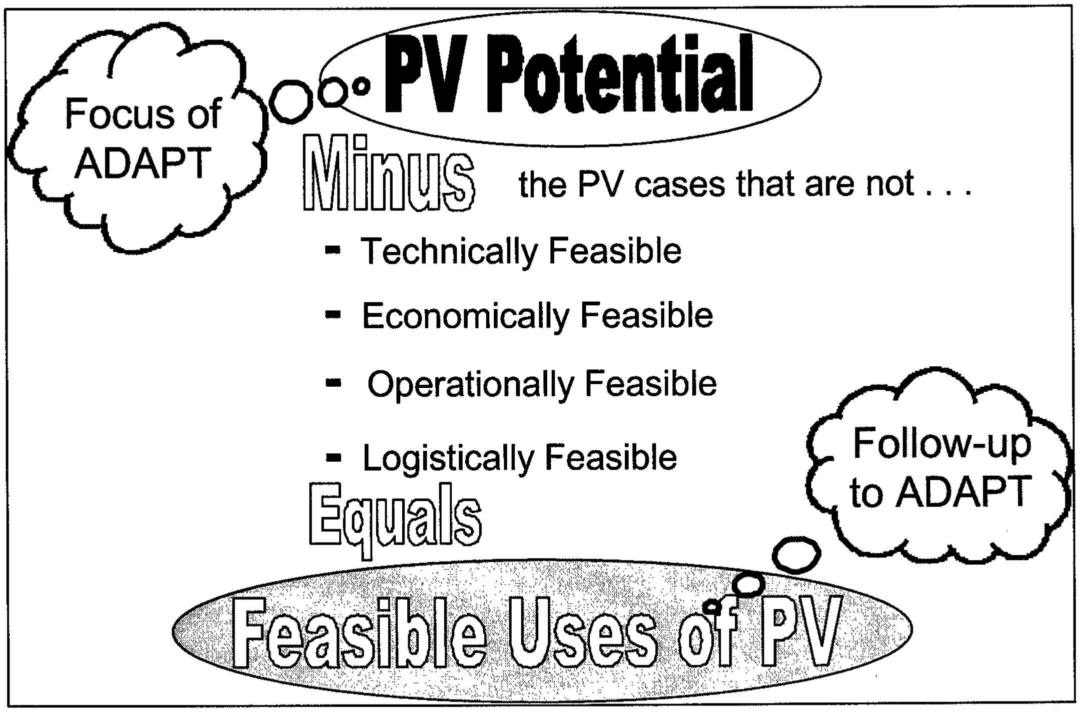


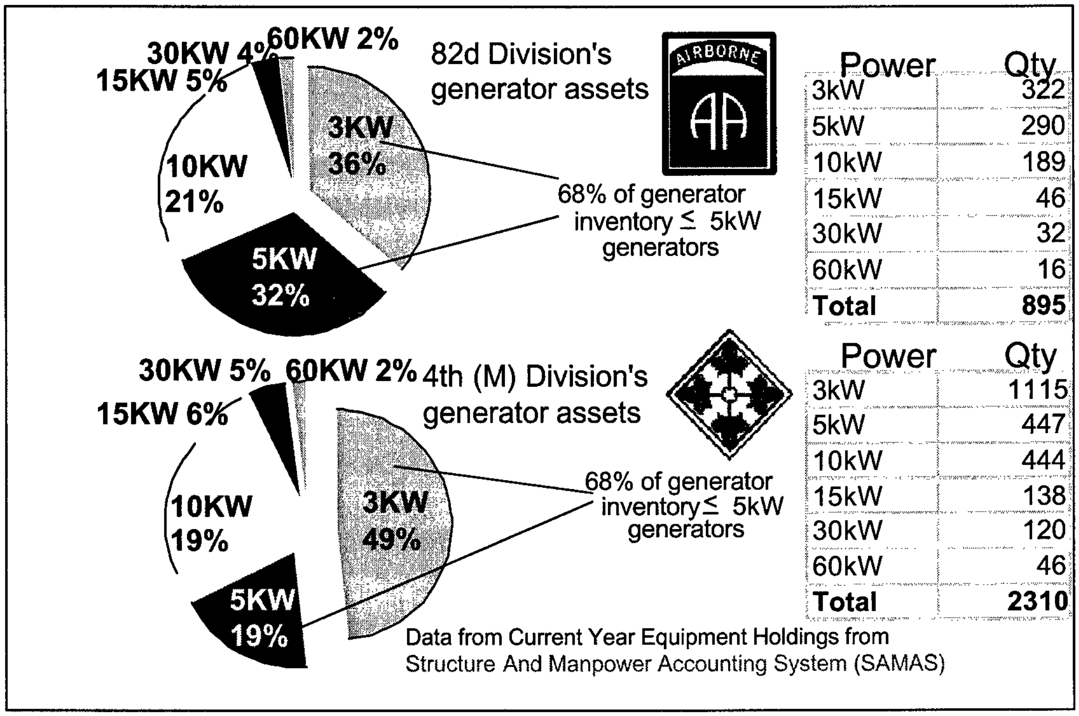
Figure 22. PV Potential vs Feasibility

First, as we have previously discussed, there are many missions that a mobile hybrid PV system can accomplish, such as (1) the battery recharge mission and (2) providing electric power to light infantry tactical operations centers. And undoubtedly there are other missions for heavier units (e.g., 3d Armored Cavalry Regiment (ACR), 4th Infantry (Mechanized)) where other prototypical variants of mobile PV can provide off-the-grid power.

However, there are likewise many missions where PV is not a good choice because of (1) readily available, cheap, on-the-grid electric power or (2) where long-term inclement weather or Alaskan "winter nights" severely reduce PV effectiveness. For whatever reason, the mission might not fit into the PV domain. Once both sets of these missions are defined and understood, then we can begin to explore--in a prioritized sense--which units would benefit best from PV. For example, light units going to JRTC at Fort Polk might benefit greatly by "falling in on" mobile PV trailers in the field. Likewise, heavier units utilizing PV power plants in the field at the NTC in Fort Irwin might also benefit from PV's quiet power and high sun radiation in the California desert. Regardless, let us now examine a small subset of potential "kilowatt candidates" to help drive missions that, from the Fort Bragg experience, we believe hybrid mobile PV can accomplish.

6.2 kW Ratings of Onhand Generators

To get a picture of the potential missions and/or applications that PV could handle can be seen from examining the Army's current table of organization and equipment (TOE) as it applies to generators.



Power	Qty
3kW	322
5kW	290
10kW	189
15kW	46
30kW	32
60kW	16
Total	**895**

Power	Qty
3kW	1115
5kW	447
10kW	444
15kW	138
30kW	120
60kW	46
Total	**2310**

Figure 23. kW Ratings of Onhand Generators

This listing of generator TOE for the 82d and for the 4th Mech, excerpted from the Requirements Validation Database--provides a breakdown of onhand, required, and authorized categories of equipment. The Army has about 60,000 generators from which Figure 23 shows the breakdown between two of its divisions: (1) 82d Airborne (Light) and (2) 4th Infantry (Mechanized - Heavy). Note that the "heavier" 4th Mechanized owns about 1,500 more generators than the "lighter" 82d. This makes sense because of the different roles and missions that each force is required to perform. Interestingly however, on a percentage basis, each division has 68 percent of its total number of generators rated in the category of 5 kilowatt or less. This indicates that the power requirement for at least this percent of applications is probably good for the missions demonstrated at Ft. Bragg.

To recalculate, not as a function of quantity of generators, but rather as a function of total kilowatt power, if each entry in the above table is multiplied (i.e., Power X Qty) and summed, this would then provide the total kilowatt power available from generators for each of these divisions. Further, if this total kilowatt power (by Division) is then divided into the available kW from generators less than or equal to 5kW, this provides the percent kW by Division for applications equal to or less than what was run for the Fort Bragg case.

6.3 PV Potential ≤ 5 kW

As discussed previously, these are the applicable percentages of available kW power--5kW and less--for each division and for the Army as a whole. In the configuration demonstrated at Ft. Bragg, photovoltaic technology has the potential to augment power from 19 to 35 percent of the Total Army's current authorized inventory of mobile generators.

82d Airborne's percent of total kWs from division's generators rated ≤ 5 kW

= 35% of 82d's total generator power

4th Mechanized's percent of total kWs from division's generators rated ≤ 5 kW

= 30% of 4th (M) total generator power

Army percent of total kWs from all active, reserve and guard generators rated ≤ 5 kW

= 19% of total Army generator power

Data from Current Year Equipment Holdings from Structure And Manpower Accounting System (SAMAS)

Figure 24. PV Potential ≤ 5 kW

6.4 Average Daily Solar Radiation (1961 - 1990)

Achieving the best solar radiation is a function of two things: (1) geographic area and (2) altitude. Figure 25 shows this function in watt hours per square inch per day. Likewise, Army mobile PV potential is also a function of the sun's radiation and altitude. The demonstration at Fort Bragg was run in 12 days of varying degrees of sun radiation. Because it was April, 6 full days were less than ideal solar radiation days due to thick cloud cover, 15-20 mph winds and intermittent heavy rain. However, the remaining time saw clear skies and temperatures in the high 80s with very little wind.

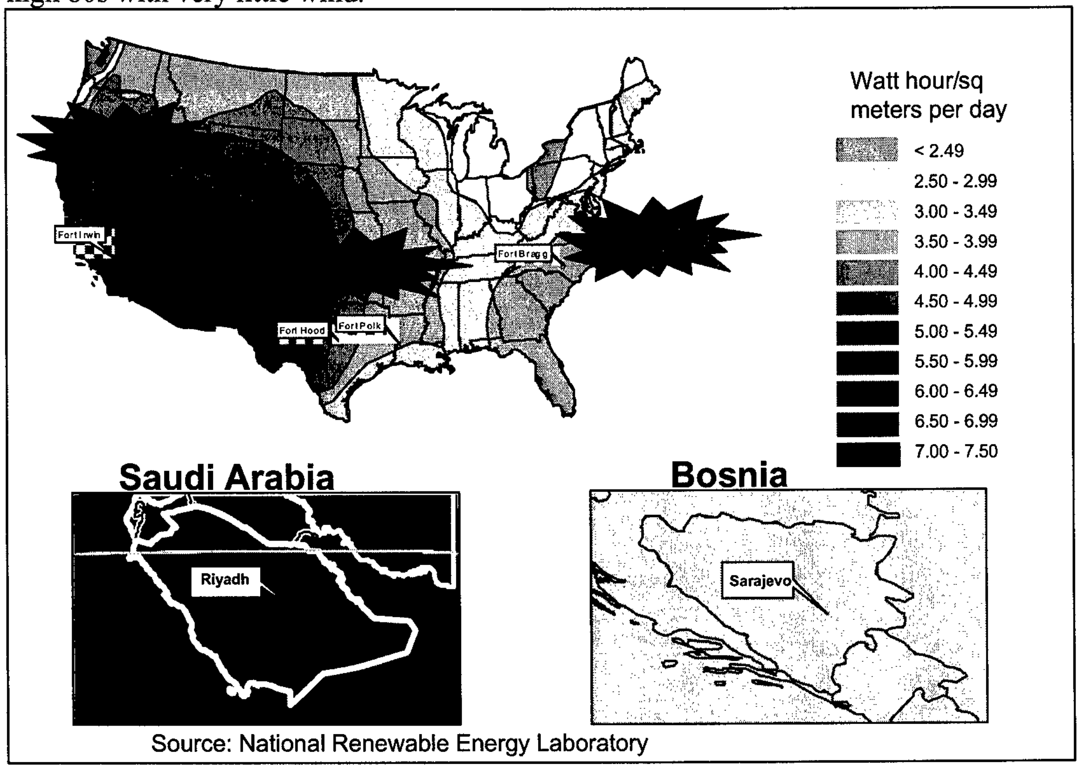


Figure 25. Average Daily Solar Radiation (1961 through 1990)

As the above map of the US indicates, North Carolina solar radiation is good, but there are better places for PV. Likewise, there are places where PV would not perform as well because of location and altitude. In CONUS, the best places for PV are obviously in the so-called sun belt and in the desert of the southwest. For example, the training center at Ft. Irwin, California--also called the National Training Center--would be ideal for photovoltaic applications. Similarly, Ft. Hood, Texas--home of III Corps, the 1st Cavalry Division, and the 4th Infantry Division (Mechanized)--would also provide very good conditions for PV power units. Areas such as these would provide considerable power for charging of the battery bank. This is not to say, however, that applications in locations where solar radiation is not as strong would be "bad"--but certainly the generator would have to run longer than the 20 percent of time advertised in the Fort Bragg demonstration.

Solar insolation values for Bosnia (seen in Figure 25) and Kosovo approximate those at Ft. Bragg while those in Saudi Arabia approximate those at the National Training Center, located near Needles, California.

6.5 US Military Deployments (1989-1999)

Figure 26 shows the last 10 years of US military deployments broken down by major command. Note from the pie chart that over 60 percent of all deployments have been to areas that were at least equal to or better than the solar radiation found at the demonstration sight at Fort Bragg.

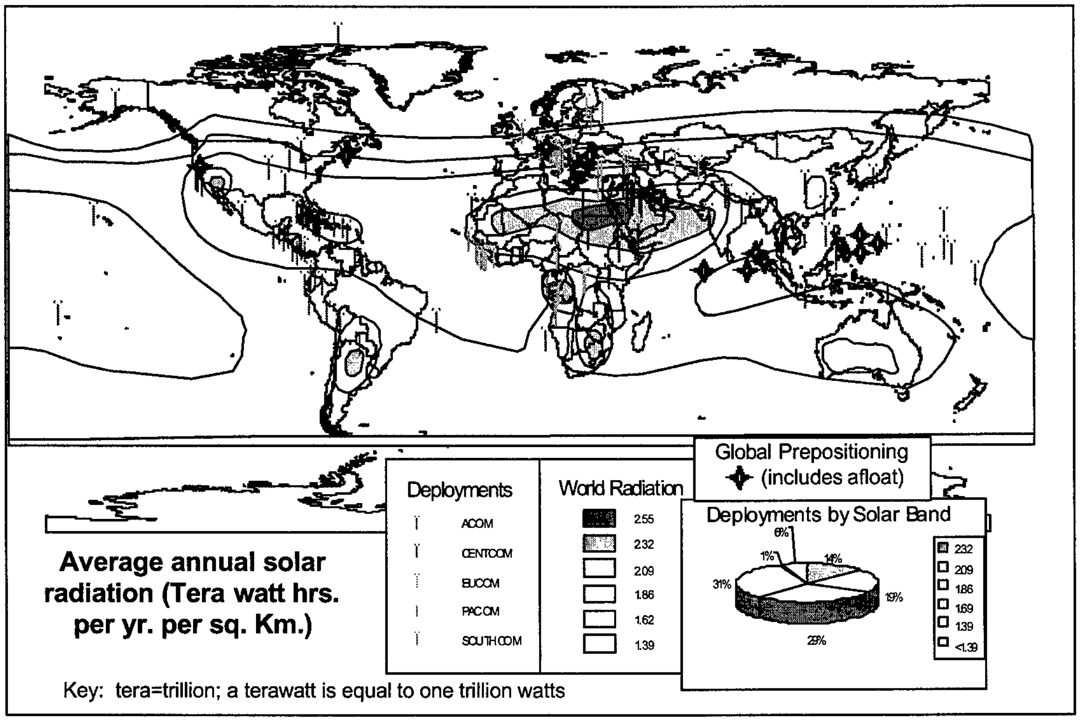


Figure 26. US Military Deployments (1989 through 1999)

This illustration was based on over 200 deployments during the past decade. Half of these deployments were to the highest sun radiation areas in or near the Arabian Gulf. Solar radiation in these areas is between 2.32 and 2.55 tera watts per year per square km.

This project demonstrated PV capabilities to army units that support PV as a viable power potential alternative. As a result, units currently stationed in Kosovo have contacted CAA about the status of this project and requested for prototypes even though they're not in an area of the world noted for good solar radiation. The 3d Battalion, 504th Parachute Infantry Regiment, located in Camp Bondsteel, Task Force 3504, Kosovo is continuing to observe weather conditions there and is providing firsthand accounts of feasible military PV applications (in writing) that they feel overcome any lack of solar radiation.

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CHAPTER 7 FINDINGS

7.1 PV and Army Strategic Responsiveness

In summary, there is ample evidence that historically, the majority of deployments to small-scale contingencies have been to areas with good solar radiation. Although this is not a guarantee that every application will be equal to or better than the demonstrated case study, it is likely that solar radiation for PV may not be a problem for the majority of deployments.

1. Two-thirds of small-scale contingencies have been in regions with solar conditions equal to or better than Ft. Bragg

2. There is demand today for PV in SSCs--e.g., Kosovo (3d Battalion, 504 Parachute Infantry Regiment, 82d Airborne - Task Force 3504)

3. Prepositioned PV can be used to supply electricity to maintain Prepositioned Equipment--e.g., Qatar, Kuwait (3d Army)

- AND -

... then be deployed as well

4. PV adds flexibility and agility to Army Forces

Figure 27. PV Improves Army Strategic Responsiveness

Today's demand for mobile PV units comes from the Army. In less developed countries that have been devastated by natural disasters or by warfare (e.g., Kosovo), troops in the field report back that local power is unreliable and inconsistent in the constant voltage levels necessary to run computer equipment. There have also been reports back from Kosovo that on occasion, fuel deliveries have been delayed or not received at all. If the Army is interested in decreasing the size of its logistics tail, certainly one should look at the capabilities that PV provides in this regard.

It was previously discussed that the best places for PV are those locations where solar radiation is exceptional and constant. These areas are well defined and many can be found in the Middle East. This area is also used for the prepositioning of equipment to be used in the event of future conflicts. These equipments must be stored in shelters currently powered by generators--far from the nearest dependable electric grid in Kuwait City. In a single day, the US Army is burning over 6,000 gallons of various fuels to supply these shelters with dehumidifying and some air conditioning power. Given enough space for PV arrays and modules in the desert (possibly 2-3 acres), the same could be done with PV.

These findings suggest that PV technologies and applications can contribute to Army strategic responsiveness by providing logistical flexibility and agility to commanders in the field.

7.2 Key Findings

1. PV can significantly contribute to Army Strategic Responsiveness
    - Domestic and International SSCs
    - Major Regional Conflicts
2. PV Enhances Readiness
    - Training Base
3. PV Case is lifecycle cost effective, prevents pollution and saves energy
4. PV complements generators
5. Significant PV potential remains untapped

Figure 28. Key Findings

It is common knowledge that FEMA is employing mobile PV power units to aid in domestic disaster relief. As early as 1992 with Hurricane David in Southern Florida to Hurricane Floyd in 1999, FEMA has made available PV power units for use by both National Guard and active duty units. Specific Army units have requested mobile PV units for use in International SSCs. For example, active duty units serving in Kosovo have requested mobile PV units to augment their TOE power supply (i.e., generators) and local "on-the-grid" power. Because many CONUS garrisons and training facilities are so large, there is usually no power available in the field--except for electricity from generators and vehicles. The Fort Bragg PV demonstration illustrated that not only could PV be used in a primary power role, it was enthusiastically endorsed by the soldiers using it. Larger applications such as at the Joint Readiness Training Center (JRTC) at Fort Polk, LA or at the National Training Center (NTC), Fort Irwin, CA are additional candidates for prototypical PV power programs.

California is a leading state in the area of pollution prevention and abatement and endorses alternatives to fossil fuel engines/generators. Because the Army has large garrisons in California (e.g., NTC, Hunter-Liggett), the fact that PV not only saves energy but dramatically reduces life cycle pollution is both a real-world and a political benefit.

In conclusion, this report developed and demonstrated a methodology for identifying the costs and benefits of using PV systems in support of the Army's initiatives in strategic responsiveness and in renewable energy. This report's PV potential analysis illustrates that ample solar radiation exists to supply energy needs in two-thirds of historically deployed SSCs. But most important of all is the fact that this energy concept is endorsed by soldiers in the field who have used it to enhance their mission.

APPENDIX A. PROJECT CONTRIBUTORS

1. PROJECT TEAM

a. Project Director

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b. Team Members

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Mr. James F. Keller, Jr.

2. PRODUCT REVIEW

Mr. Ronald J. Iekel

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82d Airborne Div, 1st Bde, 3/504th Parachute Infantry Regiment

1LT Dan Grassetti, Signal Officer
SFC Brook Reinhold, NCOIC, Commo Platoon Leader

US Army Communication Electronics Command (CECOM)

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Federal Emergency Management Agency, Region III

Dr. Jim Grichar

SunWize Technologies, Inc.

Mr. Robert Hlavaty

Sandia National Laboratories

Mr. Larry Moore

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APPENDIX B. REQUEST FOR ANALYTICAL SUPPORT

P *Performing Division:* RA *Account Number:* **99004**

A *Tasking:* Verbal *Mode (Contract-Yes/No):* No

R *Acronym:* **ADAPT**

T *Title:* Analysis of Deployable Applications of Photovoltaics in Theater

1 *Start Date:* 05-Oct-98 *Estimated Completion Date:* 31-Aug-99
Requestor/Sponsor (i.e., DCSOPS): DCSLOG *Sponsor Division:* TSE

Resource Estimates: ***a. Estimated PSM:*** 3 ***b. Estimated Funds:***

c. Models to be Used:

Description/Abstract: Develops and demonstrates a methodology for identifying and analyzing the costs and benefits of using photovoltaic (PV) systems in support of the energy needs of deployed Army forces.

Study Director/POC Signature: Original Signed *Phone#:* 703-806-5389
Study Director/POC: **Mr. Hugh Jones**

If this Request is for an External Project expected to consume 6 PSM or more Part 2 Information is Not Required. See TAB C of the Project Directors' Guide for preparation of a Formal Project Directive.

P ***Background: The use of PV has been shown to make economic and operational sense in several military applications. The economic and military value added of using PV to help provide electricity for Army operations in theater has not been assessed and needs to be explored.***

A ***Scope: Consider one theater of operations (e.g., SWA). Address monetary and nonmonetary costs and benefits. Consider Army combat and support unit missions. Only commercially PV will be included in the analysis. Period of covers the near and midterm timeframe.***

R ***Issues: Does investment in PV for theater applications provide value added?***

T ***Milestones:***

DCLOG tasker	***October 1998***
Brief Results	***February 1999***
Report published	***March 1999***

2

Signatures ***Division Chief Signature:*** *Original Signed and Dated* ***Date:***

Division Chief Concurrence:

Sponsor Signature: *Original Signed and Dated* ***Date:***

Sponsor Concurrence (COL/DA Div Chief/GO/SES) :

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GLOSSARY

AAR	after action report
ac	alternating current
ampere (A)	electrical current load, measured in coulomb/sec (1A = 1 coulomb/sec)
AMMPS	Advanced Medium-sized Mobile Power Systems
APU	auxiliary power unit (generator) mounted on a vehicle
BTU	British thermal unit (136,000 BTUs in 1 gal diesel fuel, 1kW hour = 3,412 BTUs)
CECOM	Communications and Electronics Command, Ft. Monmouth, NJ
CONUS	continental United States
dc	direct current
DOD	Department of Defense
DED	diesel engine driven
DOE	Department of Energy
FBCB2	Force XXI Battle Command Brigade and Below
FEMA	Federal Emergency Management Agency
GED	gasoline driven engine
GSA	General Services Administration
Hertz	International unit of frequency now recognized instead of cycles per second
lbs.	pounds
Mil-Std	Military standard generators currently in the field (not TQG)
MTBF	mean time between failure; for exponentially distributed failures, the MTBF is the reciprocal of the failure rate. Obsrved MTBF is equal to

	the total operating time of the equipment divided by the number of relevant failures. Observed MTBF is a point estimate.
MTBOMF	mean time between operational mission failure; that value of MTBF observed in an operational (tactical) environment as opposed to the laboratory tested value. Generally derived from user testing
NREL	National Renewable Energy Laboratory (DOE), Golden, CO
O&O	Operational and Organization Plan
OOTW	operations other than war
PM-MEP	Project Manager, Mobile Electric Power, Fort Belvoir, VA
POL	petroleum, oils, and lubricants
PV	photovoltaics, the chemical reaction of a semiconductor material to sunlight which creates the flow of electrons
rated load	a condition which results when a generator set is operating at rated frequency, rated voltage, rated current, and rated power factor as specified on the generator name plate
REQVAL	Requirements Validation data base (equipment holdings)
SAMAS	Structure and Manpower Allocation System; database (forces and force data)
SOF	Special Operations Forces
SSC	small-scale contingency
TOC	Tactical Operations Center
TQG	tactically quiet generator(s) (currently being fielded)
volt	The difference of electric potential between two points on a conducting wire carrying a constant current of 1 ampere when the power dissipated between the two points is 1 watt
watt	Measure of energy in joules per second (1 watt = 1 joule/second)